NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594

July 26, 2000

Systems Group Chairman's Factual Report Addendum Regarding the Ground and Simulation Testing

DCA-00-MA-006

A. ACCIDENT

Operator:	EgyptAir
Location:	60 Miles Southeast of Nantucket Island (N40.20, W69.45)
Date:	October 31, 1999
Time:	0148 EST
Airplane:	Boeing 767-366ER, SU-GAP

B. SYSTEMS GROUP

Chairman: Scott Warren
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Member: William Richardson
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C. SUMMARY

About 0150 eastern standard time (EST), on October 31, 1999, a Boeing 767-366ER, SU-GAP, operated by EgyptAir, as flight 990, crashed into the Atlantic Ocean about 60 miles south of Nantucket, MA. EgyptAir flight 990 was being operated under the provisions of Egyptian Civil Aviation Regulations Part 121 and United States Title 14 Code of Federal Regulations Part 129 as a scheduled, international flight from John F. Kennedy Airport (JFK), New York, New York to Cairo International Airport in Cairo, Egypt. The flight departed JFK about 0122 EST, with 4 flightcrew members, 10 flight attendants, and 203 passengers on board. There were no survivors. The airplane was destroyed by impact forces. Floating debris from the aircraft was recovered on the morning of October 31, 1999.

The systems group convened on March 29, 2000 and April 20, 2000, in Seattle, Washington to perform ground tests on a B767 aircraft that were designed to demonstrate the effects of a dual elevator PCA failure. The systems group also went to Seattle, Washington on March 31, 2000 to conduct tests using a B767 simulation that had been modified to represent the effects of a dual elevator PCA failure. All of these tests used the facilities and support of the Boeing Company.

D. DETAILS OF THE INVESTIGATION

Two 767 ground tests and a simulation session were conducted in Seattle, WA during the period of March 29 through April 20, 2000, in support of the Egypt Air 990 accident investigation. Test participants included the NTSB, Egypt Air and Egyptian CAA representatives, and various Boeing specialists. The objective of the ground test activity was to investigate and demonstrate the effects of failure conditions on the elevator system. The objective of the simulation session was to evaluate airplane controllability following these dual elevator PCA failure scenarios and to document the simulator results to allow comparison of this failure scenario data with the Egypt Air 990 FDR data.

1. Ground Tests

a) Test Airplane

Aircraft VQ001, located at Boeing Field in Seattle, WA, was used as a test bed for the ground tests. VQ001 is a 767-400ER model aircraft and is equipped with flight test instrumentation in support of certification of the 767-400ER; this instrumentation allowed the required test parameters to be recorded.

Appendix A describes the 767-400ER elevator system changes relative to the 767-300ER. VQ001 was considered an acceptable test bed by the group in which to validate the analytical predictions of the selected elevator PCA failure scenarios.

b) Test Conditions Performed

Appendix B is a copy of Test Item Planning Sheet B1.39.1316 Rev. A for the 767 Elevator Dual Failure ground test.

The objective of the ground test was the validation of the analytical predictions of the elevator PCA failure scenarios previously documented by Boeing. Testing was completed in two separate phases:

Phase I: Demonstration of single and dual PCA input failures – completed 3/29/00.

Phase II: Demonstration of dual valve jam and single input failure combined with single valve jam– completed 4/20/00

A Boeing photographer was stationed outside the airplane during both the Phase I and II ground tests and generated both video and still photographs of the tests. Also, video recordings of both the Captain's and First Officer's control columns and upper and lower EICAS displays were made during the Phase I ground test.

Phase I

The Phase I elevator dual fault ground test was conducted on 3/29/00. Two PCA failure scenarios were examined, with the failures inserted on the right elevator: (1) inboard PCA disconnected, and (2) inboard and middle PCA disconnected. Data was also recorded for the baseline condition with all PCAs connected. For each condition, column sweeps were conducted from the pilot and copilot control columns and, additionally, "split" sweeps were done with one column held fixed at neutral and the other moved fore and aft. Conditions were run at zero airspeed (base elevator feel pressure) and at 370 kts (770 psi). For some tests, the left autopilot channel was engaged and the effects of control column inputs on elevator position were also examined. Certain test conditions were repeated multiple times to allow participation by all interested test attendees.

Selected representative time history plots from the Phase I ground test are included in this report in Appendix C. For the dual elevator PCA disconnect conditions, the failed surface traveled to the elevator full travel nose down position. Control of the non-failed surface was available from either column. The asymmetry limiter did not limit differential elevator travel.

Phase II

The Phase II elevator dual fault ground test was conducted on 4/20/00. Three PCA failure scenarios were examined, with the failures inserted on the right elevator: (1) middle PCA replaced by a modified "jammed" PCA, (2) middle PCA replaced by a modified "jammed" PCA and the inboard PCA disconnected, and (3) middle and inboard PCAs replaced by modified "jammed" PCAs. For each condition, column sweeps were conducted from the pilot and copilot control columns. Conditions were run at zero airspeed (base elevator feel pressure) and at 370 kts (770 psi). Sweeps were also performed with the autopilot engaged.

Selected representative time history plots from the Phase II ground test are included as Appendix D.

For the failure scenario with one PCA replaced by a modified "jammed" PCA and one PCA disconnected, the failed surface traveled to the full travel elevator nose down position. Control of the non-failed surface was available from either column and the feel forces were the same from either column.

For the failure scenario with two jammed PCAs, the failed surface traveled to the full travel elevator nose down position. Both pilots were able to command the non-failed elevator in both nose up and nose down direction. Column movement in the elevator nose up position direction was limited during the test so as not to intentionally shear the input shear rivets at the PCA input crank on the test airplane.

Data Correction

The data collected during phases I and II was not corrected for column force biases within the instrumentation system. After the tests, the systems group requested that Boeing correct the data to eliminate this bias. Boeing provided documents containing a summary of the reasons for the column force bias, a method for correcting the data for the bias, and re-plotted data (from both test phases) that is corrected for the bias. The portions of the documents containing these items are presented as Appendix E.

2. Simulation Session

a) Test Bed

The simulation sessions were held in the 757/767 Simulator Cab at Boeing's Airplane Systems Laboratory in Seattle, WA. A summary of the specific features and capabilities added to the simulation for evaluation of the dual elevator PCA failure conditions, a list of simulation limitations, and a flow chart showing the simulation modifications are included as Appendix F. Video recording of the simulation sessions was also conducted.

b) Test Conditions Performed

The objective of the simulation session was to evaluate airplane controllability following the selected dual elevator PCA failure scenarios and to document the simulator results to allow comparison of this failure scenario data with the Egypt Air 990 FDR data. The 767-300ER aircraft simulation was used with modifications to simulate the three failure conditions: (1) Dual PCA Input Disconnect Failure, (2) One PCA Input Disconnect Plus One Input Jam Failure, and (3) Dual PCA Input Jam Failure. The test conditions included the airplane free response to the faults with no pilot input, immediate pilot corrective response, pilot corrective response after 5 seconds and pilot corrective response after 20 seconds. Appendix G contains a copy of the simulator log, which lists all flight conditions flown during the session, the failure condition, and pilots participating in each test condition.

Selected representative time history plots from the simulation session are included as Appendix H. The simulation data is plotted with the Egypt Air FDR and radar data. Note there are two pages for each figure, covering both the longitudinal axis and lateral-directional axis airplane data. All failure scenarios were recoverable to level flight, and all failure scenarios could be trimmed to hands-off level flight.

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7/26/00